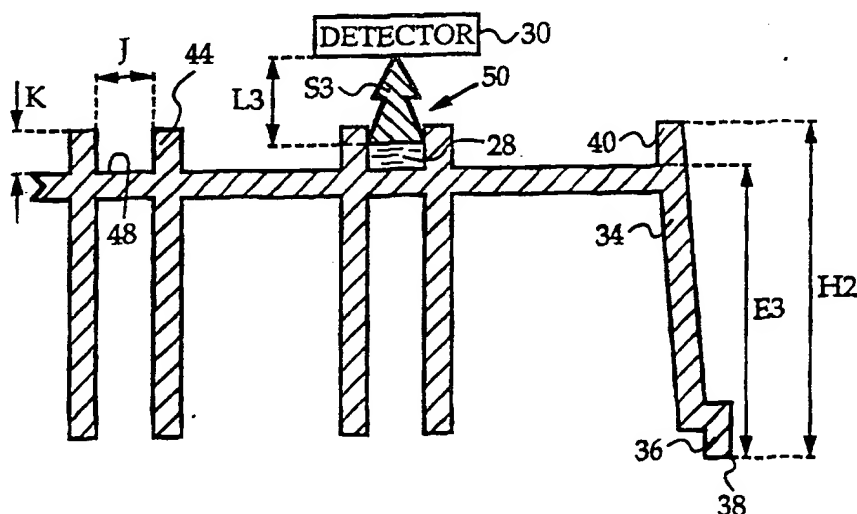




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/US98/07505 (22) International Filing Date: 14 April 1998 (14.04.98) (30) Priority Data: 08/840,553            14 April 1997 (14.04.97)            US (71) Applicant: LJI BIOSYSTEMS [US/US]; 404 Tasman Drive, Sunnyvale, CA 94089 (US). (72) Inventor: LEYTES, Lev, J.; 443 Tennyson Avenue, Palo Alto, CA 94301 (US). (74) Agent: FLOYD, Mark, B.; 426 Lowell Avenue, Palo Alto, CA 94301 (US).	(81) Designated States: JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published With international search report.	

(54) Title: MICROPLATE HAVING WELLS WITH ELEVATED BOTTOMS



## (57) Abstract

A microplate for holding mixtures (28) of reagents and samples to be assayed by emission of light signals from the mixtures to an optical detector (30) positioned above the microplate. The microplate includes a frame (34) having a base (36) and a top portion (40) extending from the base. The base has a bottom edge (38) and the top portion (40) extends to a height (H2) above the bottom edge (38). The height (H2) is preferably 14.35 mm so that the microplate is compatible with standard tray handling equipment. The microplate also includes a plurality of wells (50) disposed in the frame (34) for holding the mixtures (28). Each well has sidewalls (44) and a well bottom (48). Each well bottom is elevated a height (E3) above the bottom edge (38) of the base (36). The height (E3) is in a range of one half to nine tenths of the height (H2). The elevation of each well bottom reduces the length of the signal path (S3) from each mixture (28) to the optical detector (30) and allows a minimum quantity of reagents to be used in each well.

## 5 MICROPLATE HAVING WELLS WITH ELEVATED BOTTOMS

## RELATED APPLICATION INFORMATION

This application claims priority from U.S. application Ser. No.  
10 08/840,553 filed April 14, 1997.

## TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to multi-well bioassay  
trays, which are commonly referred to as microplates, and in  
15 particular to a microplate having wells with elevated bottoms.

## DESCRIPTION OF PRIOR ART

A microplate is often used to hold mixtures of reagents and  
samples to be assayed by techniques which are dependent upon the  
20 emission of light signals from the mixtures. The light signals  
are detected by an optical detector positioned above the  
microplate. The light signals must be sufficiently strong to be  
accurately detected. It is also desirable to use a minimum  
quantity of reagents to reduce the cost of the assay.

25 The current standard for microplates is a 96 well thermoplastic  
tray. The wells are conventionally arranged in an 8x12 array on  
9 mm centers. FIG. 1 shows a cross sectional view of a portion  
of a conventional microplate 100. Microplate 100 includes a  
30 frame 112 having a base 116 and a top portion 120 extending from  
base 116. Base 116 has a bottom edge 118. Top portion 120  
extends to a maximum height H1 above bottom edge 118. The  
current standard for height H1 is 14.35 mm.

35 Each well 114 in microplate 100 has sidewalls 122 and a bottom  
wall 124 attached to sidewalls 122. The top surface of bottom  
wall 124 forms a well bottom 126. Bottom wall 124 is typically  
1.0 mm thick and elevated a height E1 above bottom edge 118 to  
prevent scratching of bottom wall 124 when microplate 100 is

placed upon a work surface or stacked on top of another microplate. The current standard for height E1 is 1.0 mm. Well 114 typically has a volume capacity of 300 to 400 microliters for holding a mixture 128 of sample and reagent liquids.

5

A chemical reaction between the sample and reagent liquids causes the generation of a light signal. The light signal travels out of well 114 along a signal path S1 to an optical detector 130. Signal path S1 has a length L1 which is dependent upon the depth  
10 of well 114, the depth of mixture 128, and the placement of optical detector 130 above well 114. The depth of well 114 is typically 12.35 mm and optical detector 130 is generally placed 2.0 to 5.0 mm above well 114 to prevent contamination of the detector. The depth of mixture 128 is dependent upon the volume  
15 of well 114 occupied by mixture 128.

Many current assay techniques require a mixture having a volume of only 10 to 45 microliters, so that the depth of mixture 128 in well 114 is typically 0.4 to 2.0 mm. Thus, length L1 of signal  
20 path S1 is typically 12.35 to 17.0 mm. The light signals generated by a 10 to 45 microliter mixture lack sufficient strength to travel this path length and be accurately detected by detector 130. Consequently, a significant part of each signal is lost, reducing the sensitivity of the assay. The signal strength  
25 may be increased by using a much larger volume of reagents, but this practice adds significantly to the cost of the assay.

Recently, a few manufacturers have introduced 384 well plates in place of standard 96 well plates. The 384 well plates have the  
30 same frame dimensions as the 96 well plates, but the diameter of each well is reduced. The center to center distance between adjacent wells is also reduced, typically to 4.5 mm. The 384 well plates have the same disadvantage of creating a prohibitively long signal path between each sample mixture and an  
35 optical detector placed above the mixture. The problem of accurate signal detection is further compounded with 384 well plates because their reduced well diameter creates an even narrower signal path from the bottom of each well to the optical

detector. Thus, a significant part of each signal is lost, reducing the sensitivity of the assay.

#### OBJECTS AND ADVANTAGES OF THE INVENTION

5 In view of the above, it is an object of the present invention to provide a microplate which reduces the volume of reagent required in each well. It is another object of the invention to provide a microplate which reduces the length of the signal path from the bottom of each well to an optical detector positioned above the  
10 microplate, thereby increasing the sensitivity of an assay.

These and other objects and advantages will become more apparent after consideration of the ensuing description and the accompanying drawings.

15

#### SUMMARY

The invention presents a microplate for holding mixtures of reagents and samples to be assayed by emission of light signals from the mixtures to an optical detector positioned above the  
20 microplate. The microplate includes a frame having a base and a top portion extending from the base. The base has a bottom edge and the top portion extends to a first height above the bottom edge. The first height is in a range of 12.0 to 16.0 mm, with a preferred value of 14.35 mm so that the microplate is compatible  
25 with standard plate handling equipment.

The microplate also includes a plurality of wells disposed in the frame for holding the mixtures. In the preferred embodiment, the wells are disposed in an eight-by-twelve rectangular array such  
30 that the center of each well is spaced 9.0 mm from the center of each horizontally adjacent well and spaced 9.0 mm from the center of each vertically adjacent well. This standard 9.0 mm center to center spacing ensures that the microplate is compatible with conventional liquid transfer equipment. In a second embodiment,  
35 the wells are disposed in a sixteen-by-twenty-four rectangular array such that the center of each well is spaced 4.5 mm from the center of each horizontally adjacent well and spaced 4.5 mm from the center of each vertically adjacent well.

Each well has sidewalls and a well bottom. The well bottom is elevated a second height above the bottom edge of the base. The second height is in a range of one half to nine tenths of the first height. The elevation of each well bottom reduces the length of the signal path from each mixture to the optical detector and allows a minimum quantity of reagents to be used in each well.

#### BRIEF DESCRIPTION OF THE DRAWINGS

- FIG. 1 is a cross sectional view of a portion of a conventional microplate.
- FIG. 2 is a top plan view of a microplate according to a preferred embodiment of the invention.
- FIG. 3 is a cross sectional view of the microplate of FIG. 2 taken along the line A - A' in FIG. 2.
- FIG. 4 is a cross sectional view of a well disposed in the microplate of FIG. 2.
- FIG. 5 is a cross sectional view of other wells according to the invention.
- FIG. 6 is a cross sectional view of wells having V-shaped bottoms according to the invention.
- FIG. 7 is a cross sectional view of wells having U-shaped bottoms according to the invention.
- FIG. 8 is a cross sectional view of wells having individual filter plug bottoms according to the invention.
- FIG. 9 is a cross sectional view of wells having filter bottoms formed from a sheet of filter material.
- FIG. 10 is a top plan view of a microplate having well strips according to the invention.
- FIG. 11 is a cross sectional view of the microplate of FIG. 10.
- FIG. 12 is a top plan view of another microplate according to the invention.

#### DETAILED DESCRIPTION

A preferred embodiment of the invention is shown in FIGS. 2-4. FIG. 2 shows a top plan view of a microplate 32 having a frame 34 and ninety-six wells 42. Wells 42 are disposed in frame 34 in an eight-by-twelve rectangular array such that the center of each

well is spaced a distance C from the center of each horizontally adjacent well. The center of each well is also spaced a distance C from the center of each vertically adjacent well. Distance C is preferably 9.0 mm so that microplate 32 is compatible with standard liquid transfer equipment.

FIG. 3 shows a cross section of the microplate taken along the line A - A' in FIG. 2. Frame 34 has a base 36 and a top portion 40 extending from base 36. Base 36 has a bottom edge 38. Top portion 40 extends to a first height H2 above bottom edge 38. Height H2 is preferably in the range of 12.0 to 16.0 mm, with a preferred value of 14.35 mm. The height of 14.35 mm is presently preferred so that the microplate is compatible with standard plate handling equipment.

Each well 42 has sidewalls 44 extending vertically to a second height above bottom edge 38. The second height is preferably equal to height H2. Each well also has a bottom wall 46 whose upper surface forms a well bottom 48. In the preferred embodiment, each well bottom 48 is flat. Bottom wall 46 is attached to sidewalls 44 such that each well bottom is elevated a third height E2 above bottom edge 38. Height E2 is one half to nine tenths of height H2. Thus, in the preferred embodiment, height E2 is in the range of 6.0 to 14.4 mm with a preferred range of 7.2 to 12.9 mm when height H2 is equal to 14.35 mm.

FIG. 4 shows a detailed cross sectional view of the structure of each well. Each well is designed to hold a mixture 28 of reagent and sample liquids to be assayed by the emission of light signals from mixture 28 to an optical detector 30. Mixture 28 has a depth I which is dependent upon a volume V of mixture 28. Detector 30 is positioned a height G above the well. Height G is selected such that detector 30 is located as close as possible to the well without becoming contaminated by samples and reagents. Height G is typically 2.0 to 5.0 mm with a preferred value of 3.0 mm.

In the preferred embodiment, each well has a diameter D in the range of 6.0 to 8.0 mm with a preferred value of 7.0 mm. Also in

the preferred embodiment, each well has a depth **F** in the range of 1.5 to 7.1 mm with a preferred value of 3.0 mm. The diameter and depth of each well is preferably selected such that the well has a volume capacity of 100 to 150 microliters. Microplate 32 is easily fabricated using conventional injection molding techniques and is preferably a single molded plastic part.

The operation of the preferred embodiment is illustrated in FIG. 4. A chemical reaction between the sample and reagent liquids causes the generation of a light signal. The light signal travels out of the well along a signal path **S2** to optical detector 30. Signal path **S2** has a length **L2**, where  $L2 = F + G - I$ . Depth **I** is calculated by the following equation:

$$I = \frac{V}{\pi(D/2)^2}$$

For example, when diameter **D** equals 7.0 mm, depth **I** ranges from 0.25 to 1.2 mm as volume **V** ranges from 10 to 45 microliters. Thus, when using the preferred values of depth **F** and height **G** given above, length **L2** of signal path **S2** ranges from 4.80 to 5.75 mm as volume **V** ranges from 10 to 45 microliters. The light signal generated by a 10 to 45 microliter mixture of sample and reagents is capable of traveling this path length with sufficient strength to be accurately detected by detector 30.

Thus, microplate 32 provides a significant improvement over conventional microplates by allowing sensitive assays to be performed with a minimum quantity of reagents. The microplate improves the accuracy of the assay while simultaneously reducing costs. A further advantage of microplate 32 is that it achieves both of these goals while maintaining the frame dimensions and well center spacing necessary to be compatible with standard plate handling and liquid transfer equipment.

FIG. 5 shows a second embodiment of the invention in which the microplate includes a plurality of wells 50 in place of wells 42. Wells 50 are preferably disposed in frame 34 in the same manner as wells 42, e.g. 96 wells arranged in an 8x12 array on 9.0 mm centers. However, wells 50 differ from wells 42 in that wells 50

have a smaller volume capacity for smaller volume applications. Each well 50 has a diameter J in the range of 2.0 to 5.0 mm and a depth K in the range of 1.5 to 4.0 mm. The diameter and depth of each well 50 is preferably selected such that each well has a  
5 volume capacity of 10 to 50 microliters.

In operation, light signals from mixture 28 travel to detector 30 along a signal path S3. Signal path S3 is narrower than signal path S2 due to the smaller diameter of wells 50 relative to wells  
10 42. To compensate for the narrower signal path, each well bottom 48 is elevated to a height E3 above bottom edge 38. Height E3 is preferably seven tenths to nine tenths of height H2, e.g. 10.0 to 12.9 mm when height H2 is equal to 14.35 mm. This elevation of each well bottom 48 ensures that optical detector 30 receives  
15 an adequate signal from mixture 28. Other than the differences described, the operation and advantages of the second embodiment are the same as the preferred embodiment described above.

FIGS. 6 - 7 illustrate alternative embodiments of the microplate  
20 in which the well bottoms have different shapes. FIG. 6 shows wells 52 having V-shaped well bottoms. Wells 52 are preferably disposed in frame 34 in the same manner as the wells of the preferred embodiment, e.g. 96 wells arranged in an 8x12 array on 9.0 mm centers. However, wells 52 differ from the wells of the  
25 preferred embodiment in that wells 52 have bottom walls 54 whose upper surfaces form V-shaped well bottoms 56. Bottom walls 54 are positioned such that the lowest point of each well bottom 56 is elevated height E2 above edge 38.

30 FIG. 7 shows wells 58 having U-shaped well bottoms. Wells 58 are preferably disposed in frame 34 in the same manner as the wells of the preferred embodiment, e.g. 96 wells arranged in an 8x12 array on 9.0 mm centers. However, wells 58 differ from the wells of the preferred embodiment in that wells 58 have bottom walls 60  
35 whose upper surfaces form U-shaped well bottoms 62. Bottom walls 60 are positioned such that the lowest point of each well bottom 62 is elevated height E2 above bottom edge 38.



FIGS. 8 - 9 illustrate alternative embodiments of the microplate in which the well bottoms are formed by filter material. FIG. 8 shows wells 76 having well bottoms 80 formed by individual filter plugs 78. Wells 76 are preferably disposed in frame 34 in the same manner as the wells of the preferred embodiment, e.g. 96 wells arranged in an 8x12 array on 9.0 mm centers. Filter plugs 78 are positioned such that each well bottom 80 is elevated height E2 above bottom edge 38.

Each filter plug is preferably press fit between the sidewalls of a respective well. Alternatively, each filter plug may be ultrasonically bonded or adhesively bonded to the sidewalls of a respective well. One advantage of the current invention is that filter plugs 78 may have a thickness ranging up to height E2 and still fit within frame 34. Filter bottoms are typically thicker than non-filter bottoms, and their greater thickness often makes them difficult to fit to conventional microplates.

FIG. 9 shows wells 64 having well bottoms 68 formed by a single filter sheet 70. Wells 64 are preferably disposed in frame 34 in the same manner as the wells of the preferred embodiment, e.g. 96 wells arranged in an 8x12 array on 9.0 mm centers. Sheet 70 is positioned such that each well bottom 68 is elevated height E2 above bottom edge 38. Each well 64 has respective sidewalls 66 to which sheet 70 is attached. Sheet 70 includes barrier sections 82 disposed below the sidewalls of each well. Barrier sections 82 prevent liquid transfer between adjacent wells.

Sheet 70 is preferably attached to the sidewalls of each well by ultrasonic bonding. In this process, the top surface of sheet 70 is held firmly pressed to the bottom surfaces of the sidewalls. Sheet 70 is then bonded to the sidewalls by the application of ultrasonic energy which causes the contacting surfaces to fuse together. The fusing of the contacting surfaces forms barrier sections 82. Alternatively, sheet 70 may be press fit and adhesively bonded to frame 34. As sheet 70 is press fit, force of contact between the top surface of sheet 70 and the bottom surfaces of the sidewalls compresses sheet 70 below the

contacting surfaces. The compression of sheet 70 forms barrier sections 82.

FIGS. 10 - 11 illustrate a third embodiment of the invention.

- 5 FIG. 10 shows a top plan view of a microplate 84 having a frame 86 and a number of well strips 88 removably disposed in frame 86. Frame 86 has a rim 87 for holding well strips 88. The number of well strips disposed in frame 86 at any given time may be varied to tailor microplate 84 to a specific application. Frame 86 is  
10 preferably sized to hold at least eight well strips concurrently. Each well strip 88 forms a single row of wells 90. Wells 90 are preferably formed in each well strip such that the center of each well is spaced 9.0 mm from the center of each adjacent well. Frame 86 and well strips 88 may be easily fabricated using  
15 conventional injection molding techniques.

- FIG. 11 shows a cross sectional view of one of well strips 88 disposed in frame 86. Frame 86 includes a base 36 having a bottom edge 38. Frame 86 extends to height H2 above bottom edge  
20 38. Each well 90 formed in the well strip has sidewalls 92 and a bottom wall 94 whose upper surface forms a well bottom 96. Each well bottom is elevated height E2 above bottom edge 38, as previously described in the preferred embodiment above. The advantage of the third embodiment is that it allows wells to be  
25 easily added and removed from the microplate. Other than the differences described, the operation and advantages of the third embodiment are the same as those described in the preferred embodiment above.

- 30 FIG. 12 shows a top plan view of an alternative microplate 74 having 384 wells disposed in a sixteen-by-twenty-four (16x24) rectangular array. The wells are disposed such that the center of each well is spaced a distance Y from the center of each horizontally and vertically adjacent well. Distance Y is  
35 preferably 4.5 mm. Each well in microplate 74 has an elevated well bottom which may be a flat bottom, V-shaped bottom, U-shaped bottom, or filter bottom as previously described. Microplate 74 is easily fabricated using conventional injection molding techniques. The advantage of microplate 74 is that it allows a

greater number of samples to be concurrently assayed for high throughput screening applications.

#### SUMMARY, RAMIFICATIONS, AND SCOPE

5 Although the above description includes many specificities, these should not be construed as limitations on the scope of the invention, but merely as illustrations of some of the presently preferred embodiments. Many other embodiments of the invention are possible. For example, in one alternative embodiment, the  
10 wells have tapered sidewalls to further reduce the volume of reagent required in each well.

In another embodiment, the wells are square rather than round. Round wells are illustrated in the preferred embodiment due to  
15 their predominant use in industry, but the microplate of the present invention is also effective with wells having different shapes. Further, the above embodiments describe wells arranged in 8x12 and 16x24 rectangular arrays. However, the microplate of the present invention may include any number of wells arranged in  
20 any format, e.g. 6 wells arranged in a 2x3 array, 24 wells arranged in a 4x6 array, 48 wells arranged in a 6x8 array, etc.

Therefore, the scope of the invention should be determined not by the examples given, but by the appended claims and their legal  
25 equivalents.

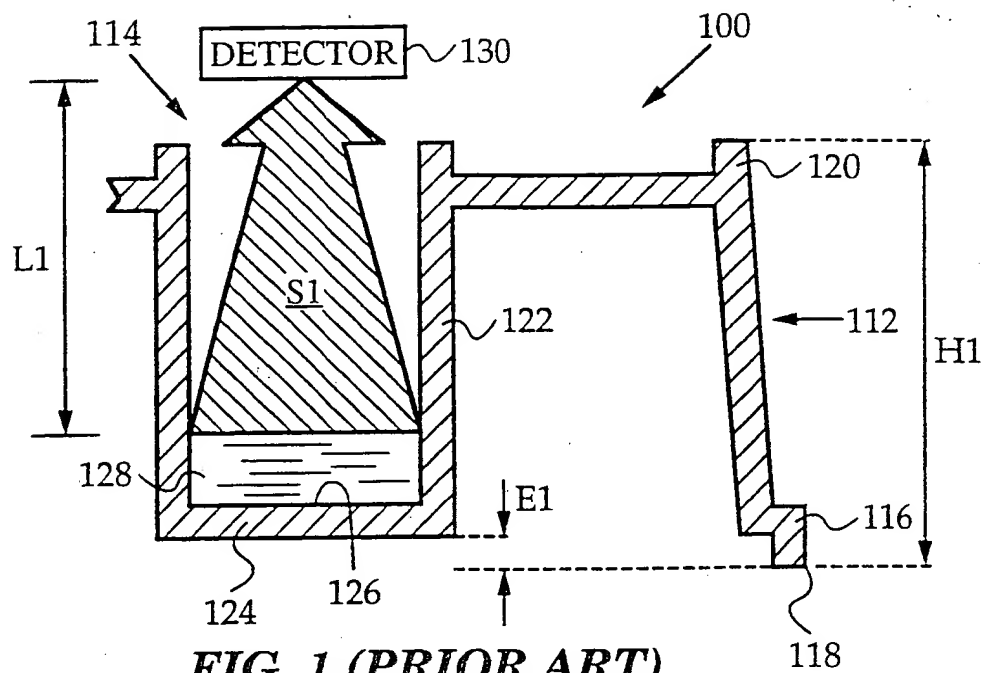
## CLAIMS

What is claimed is:

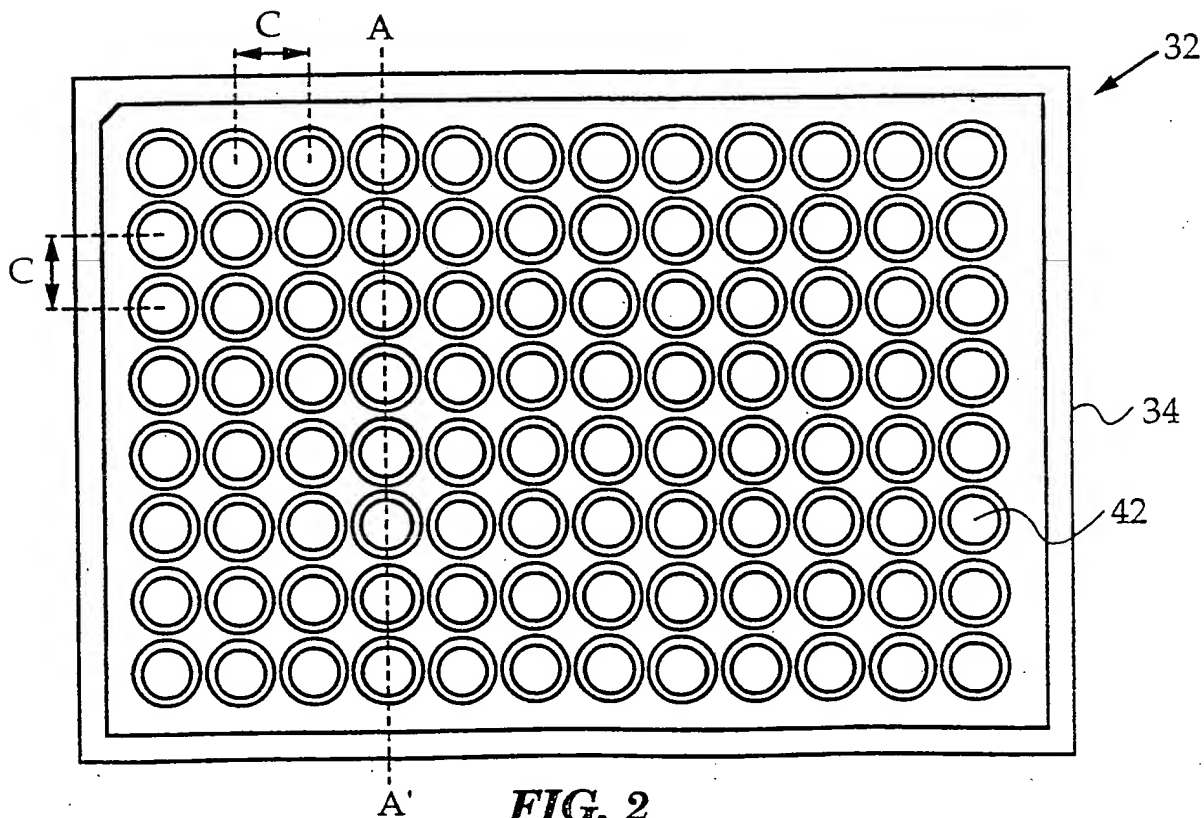
- 1 1. A microplate for holding mixtures of reagents and samples to  
2 be assayed by emission of light signals from said mixtures to  
3 an optical detector positioned above said microplate, said  
4 microplate comprising:
  - 5 a) a frame having a bottom edge, said frame extending to a  
6 first height above said bottom edge; and
  - 7 b) a plurality of wells disposed in said frame for holding  
8 said mixtures, each said well having sidewalls and a well  
9 bottom, said well bottom being elevated a second height  
10 above said bottom edge, said second height being in a  
11 range of one half to nine tenths of said first height.
- 12 2. The microplate of claim 1, wherein said first height is in  
1 a range of 12.0 to 16.0 mm and said second height is in a  
2 range of 6.0 to 14.4 mm.
- 3 3. The microplate of claim 2, wherein said first height  
4 is about 14.35 mm.
- 5 4. The microplate of claim 1, wherein each said well has a  
6 diameter in the range of 6.0 to 8.0 mm and a depth in the  
7 range of 1.5 to 7.1 mm.
- 8 5. The microplate of claim 1, wherein each said well has a  
9 diameter in a range of 2.0 to 5.0 mm and a depth in a  
10 range of 1.5 to 4.0 mm.
- 11 6. The microplate of claim 1, wherein said wells are disposed  
12 in an eight-by-twelve rectangular array such that the  
1 center of each said well is spaced 9.0 mm from the center  
2 of each horizontally adjacent well and spaced 9.0 mm from  
3 the center of each vertically adjacent well.
- 4 7. The microplate of claim 1, wherein said wells are disposed  
5 in a sixteen-by-twenty-four rectangular array such that  
6 the center of each said well is spaced 4.5 mm from the

- 4 center of each horizontally adjacent well and spaced 4.5  
5 mm from the center of each vertically adjacent well.  
6
- 1 8. The microplate of claim 1, wherein said wells are formed  
2 by at least one well strip removably disposed in said  
3 frame.  
4
- 1 9. The microplate of claim 1, wherein said well bottom is  
2 flat.  
3
- 1 10. The microplate of claim 1, wherein said well bottom is V-  
2 shaped.  
3
- 1 11. The microplate of claim 1, wherein said well bottom is U-  
2 shaped.  
3
- 1 12. The microplate of claim 1, wherein said well bottom is  
2 formed by filter material.  
3
- 1 13. The microplate of claim 12, wherein said filter  
2 material comprises an individual filter plug.  
3
- 1 14. The microplate of claim 12, wherein said filter  
2 material comprises a filter sheet.  
3
- 1 15. The microplate of claim 14, wherein said filter  
2 sheet includes barrier sections disposed below the  
3 sidewalls of said wells for preventing liquid  
4 transfer between adjacent wells.  
5

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**FIG. 1 (PRIOR ART)**



**FIG. 2**

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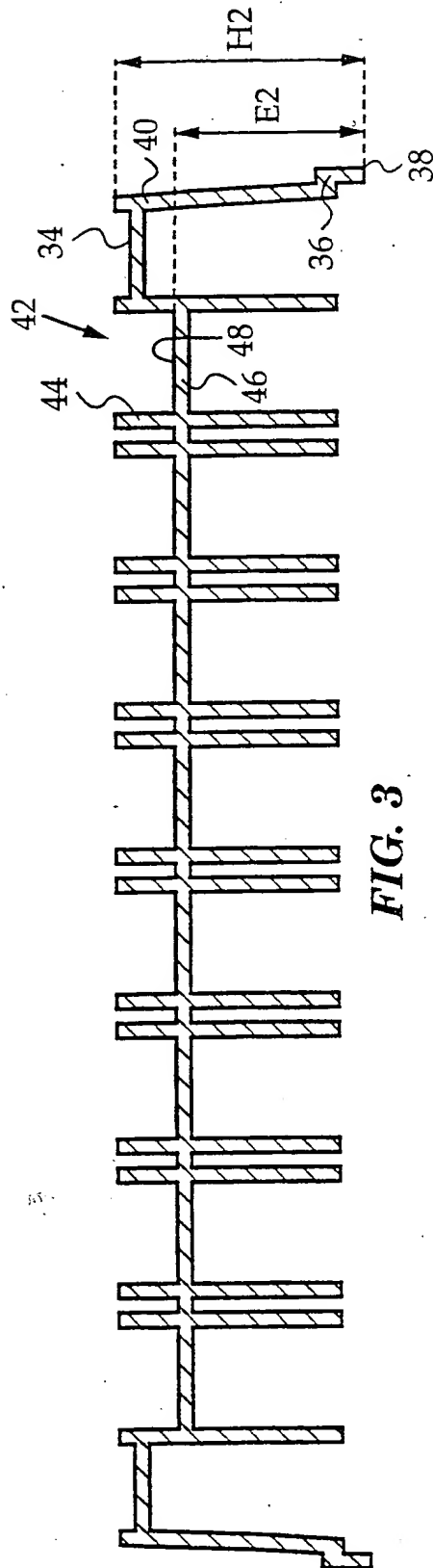


FIG. 3

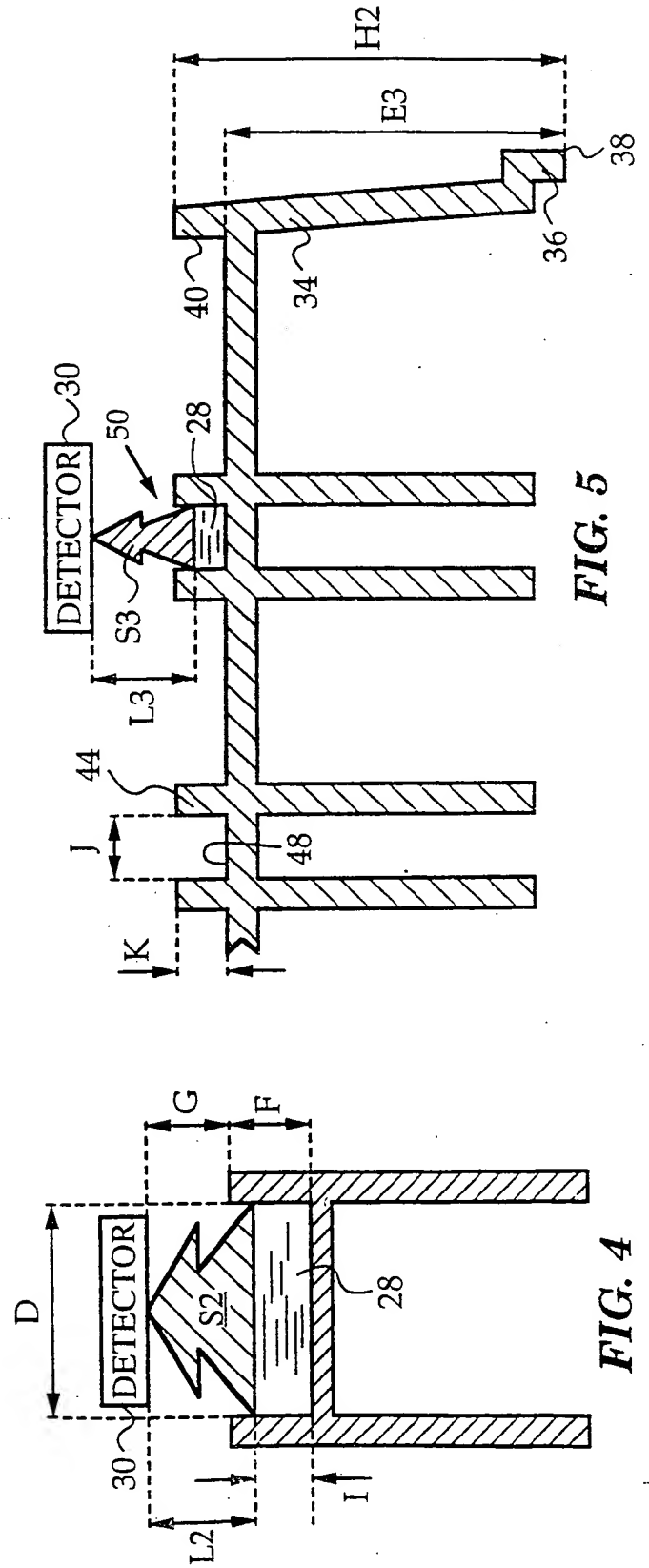


FIG. 5

FIG. 4

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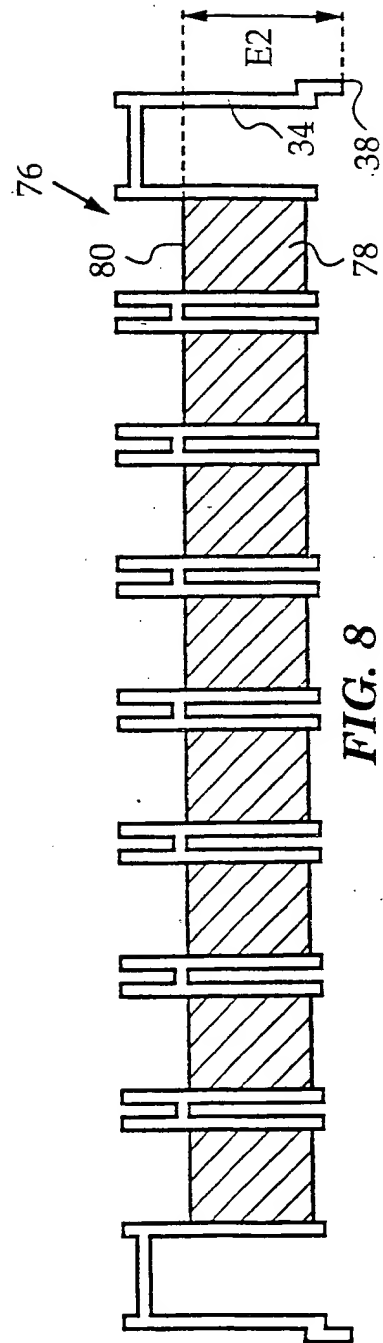
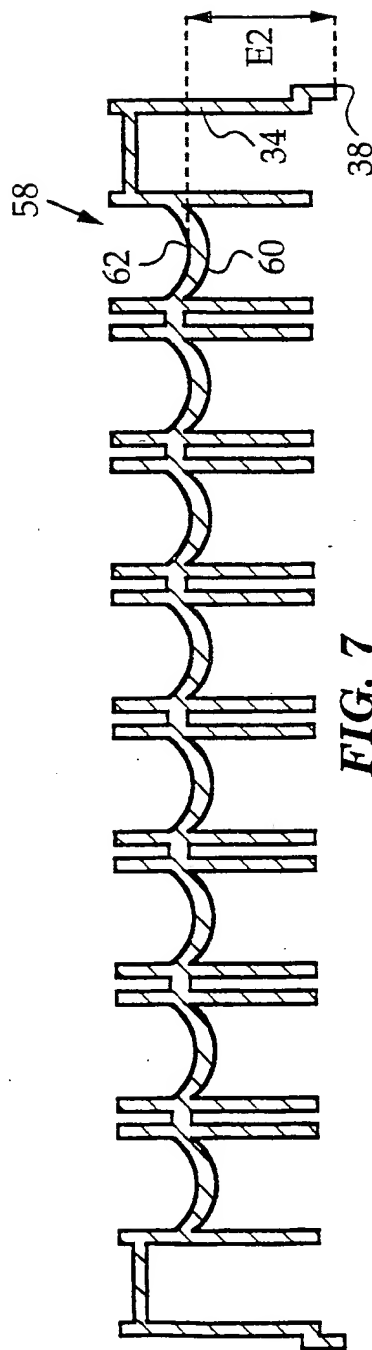
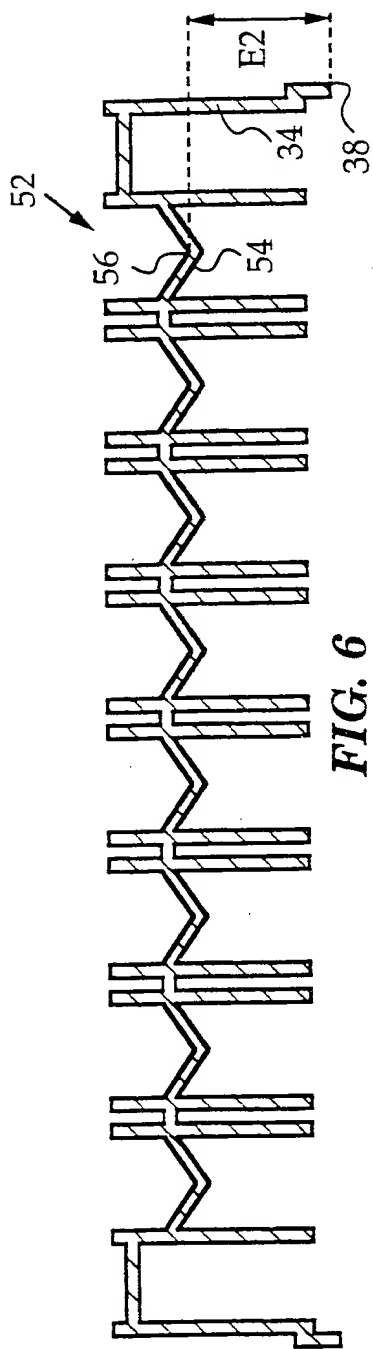


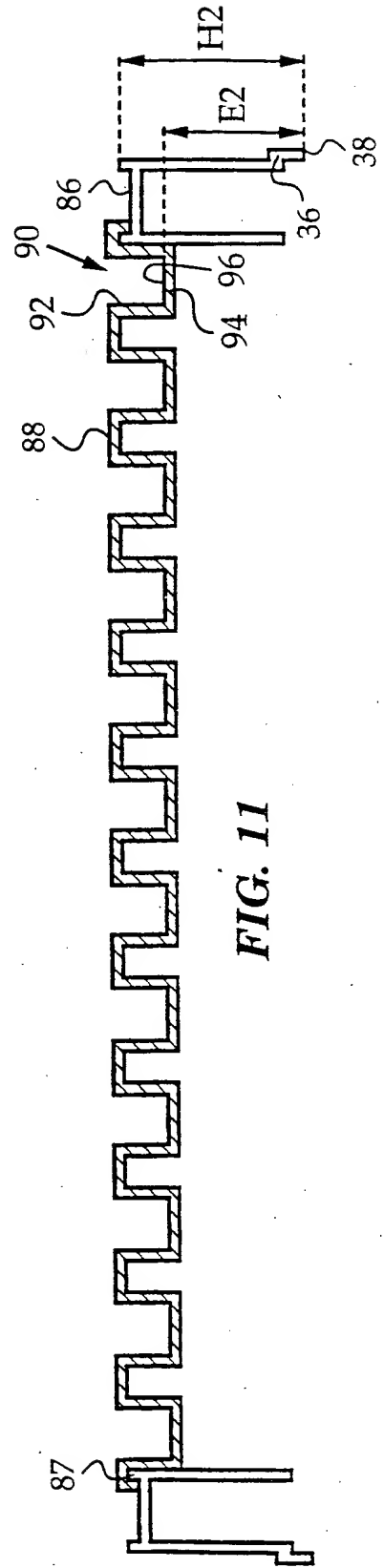
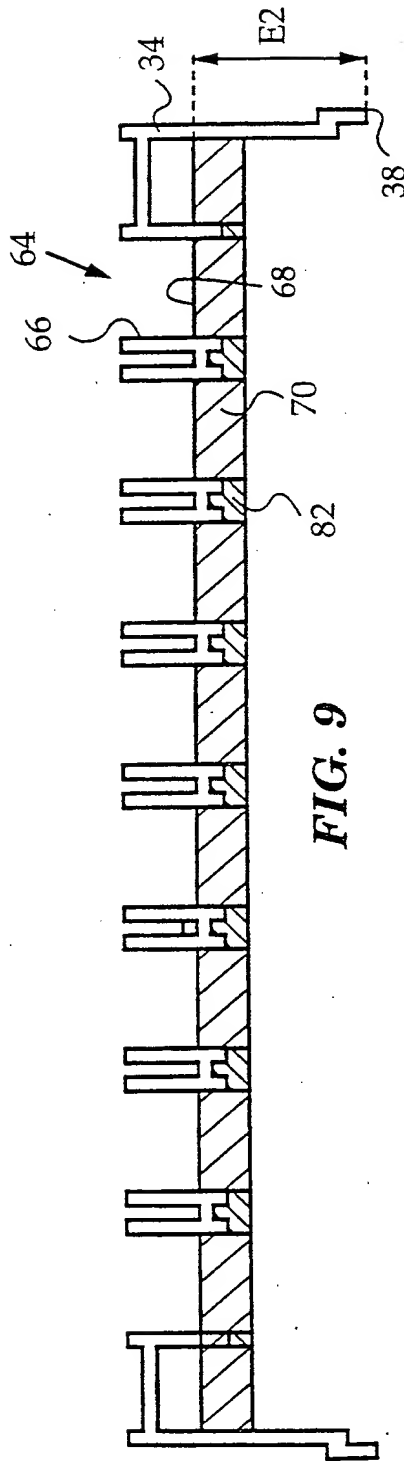
FIG. 6

FIG. 7

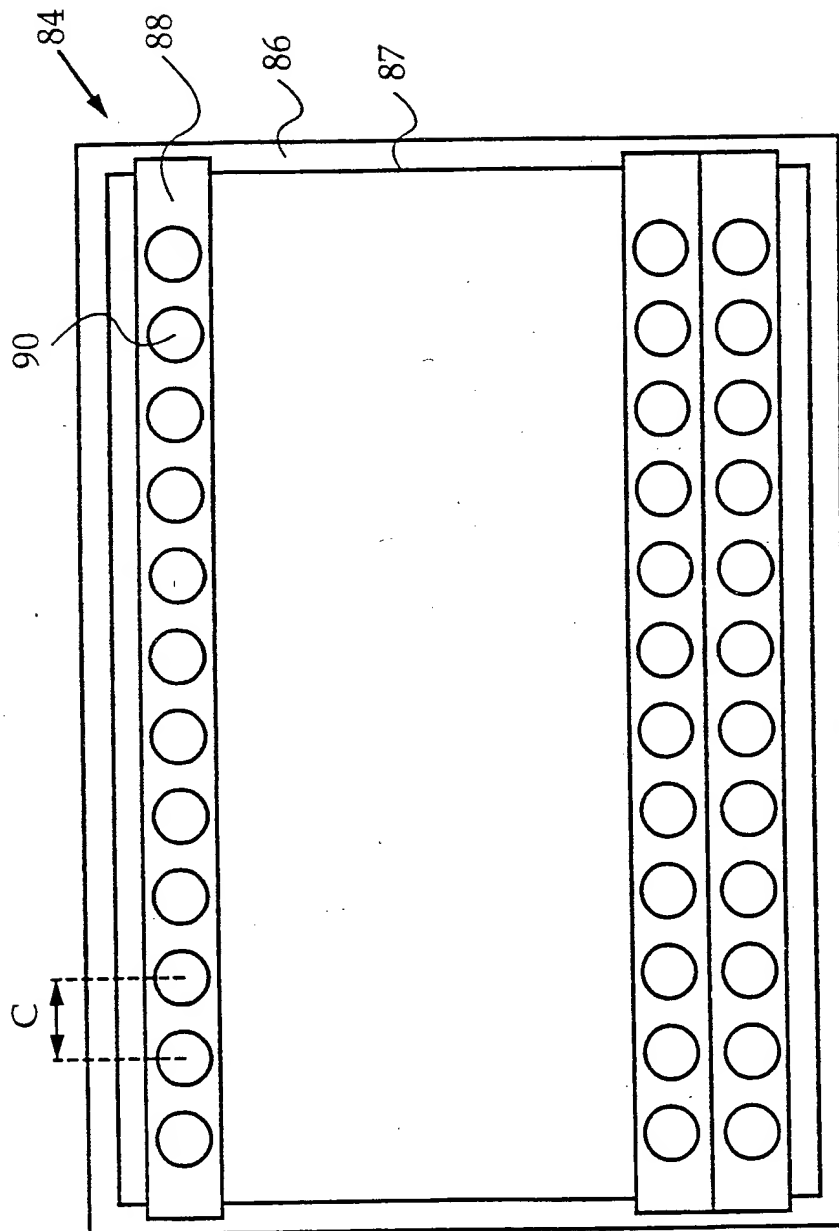
FIG. 8



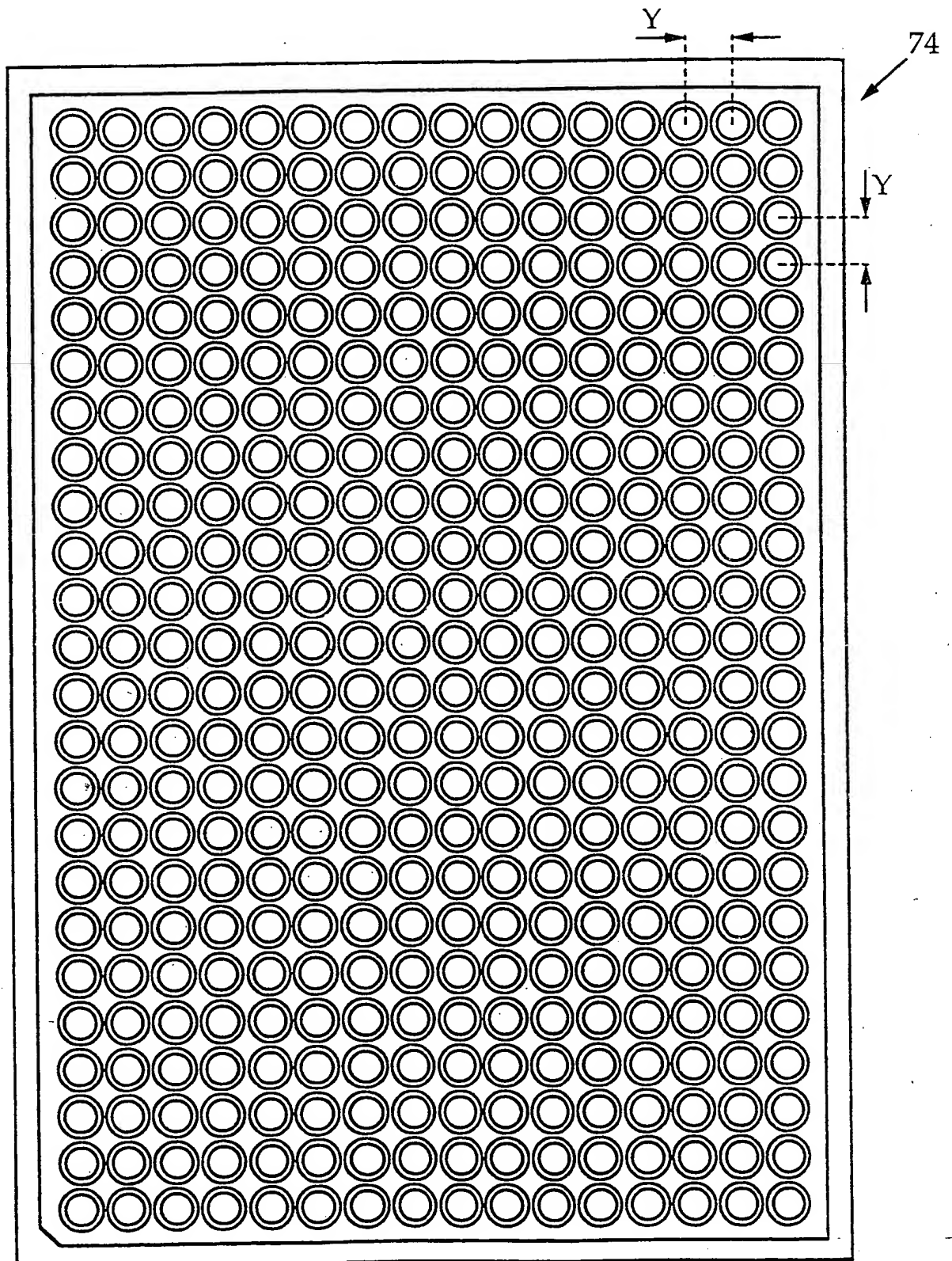
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**FIG. 10**

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**FIG. 12**

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/07505

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G01N 21/03

US CL : 356/246

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 356/246. 436, 440

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,704,255 (JOLLEY) 3 November 1987 (03/11/87), col. 8, lines 22-32.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	* T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
* A* document defining the general state of the art which is not considered to be of particular relevance	* X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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08 JUNE 1998

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